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AN ACOUSTIC-NOISE REDUCTION MODIFICATION KIT FOR THE AN/TPS-32 RADAR SYSTEM

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PROBLEM

Phase I (subject of present report): Develop several alternate methods to control and/or reduce the AN/TPS-32 radar acoustical noise to a safe level, and select the most promising method.

Phase II (after approval of recommended method): Construct, install, and evaluate one complete acoustical-noise reduction modification kit for the AN/TPS-32 radar system.

RESULTS

1. Using the AN/TPS-32 installation at the Marine Corps Tactical System Support Activity, MCAS, Santa Ana, California as a basis for the survey, extensive measurements were made of sound-pressure levels around the area of the radar shelters. Sources of noise were identified.

2. Measurements are interpreted in terms of potential damage to hearing, effects on speech communications, and certain nonauditory effects.

3. Noise levels measured in the survey are compared to permissible limits of sound level and exposure time established by applicable federal legislation and by the Naval Bureau of Medicine and Surgery.

4. Six techniques are proposed for reducing or controlling acoustic noise in the AN/TPS-32 radar shelters; these are described and compared in terms of effectiveness, complexity, and cost.

RECOMMENDATIONS

Of the techniques studied, the one recommended removes the noise hazard without the use of items that would have to be removed and stowed during transporting of the radar system. The modification kit includes:

1. Some new fans, sound-absorbing material, and duct and louvered silencers to reduce the level of the directly radiated noise.

2. Vibration-isolating materials to reduce the transmission of vibration to radiating surfaces.

3. Sensing circuits to control the air flow and thus reduce the severity of corrosion.

ADMINISTRATIVE INFORMATION

Work was performed under X3118 (NELC N529), by members of the Human Factors Technology Division. This report covers work from April 1972 to January 1973, and was approved for publication on 25 April 1973.

The authors wish to express their appreciation to Dr. J. C. Webster, who furnished valuable assistance in preparing the manuscript of this report.

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BACKGROUND

In May 1971, surveys of the AN/TPS-32 radar system as installed and used at the Marine Corps Air Station (MCAS) (Helicopter), Santa Ana, California, found sound levels exceeding those permissible for 3- to 8-hour exposures.[1] This excessive noise produces a twofold adverse effect: it impairs speech communication and it presents a hazard to the hearing of the personnel who operate and maintain the radar or work in proximity to it. Both drawbacks are of continuing concern to the Navy and have been the subject of many studies in various situations. In May 1972, NELC was tasked by NAVELEX[2] to design and develop a noise-reduction modification kit that would remove the noise hazard around the AN/TPS-32 radar installation.

SCOPE OF STUDY

This report covers Phase I of a two-phase problem. Phase I involves definition of the total noise environment of the AN/TPS-32 radar installation and the degree of hearing hazard it presents to personnel; location of noise sources; and measurement of sound-spectrum levels at each source. The Phase I assignment also required that several alternative methods be developed to control or reduce the AN/TPS-32 acoustical noise, and the most promising method chosen. Such a choice was made and will be discussed and illustrated.

Phase II will involve construction, installation, and evaluation of one complete acoustical-noise reduction modification kit for the AN/TPS-32 radar system.

EFFECTS OF NOISE ON PEOPLE

Noise produces various effects on people, depending on its intensity, duration, and frequency of exposure. Reference 3 states:

". . . it is well known and documented that noise from 75 dBA up will produce various temporary changes in the physiological state. The most important of these is a reduction in the size of the median and smaller arterioles (small terminal twigs of arteries that end in capillaries). Some of the side effects of this phenomenon are an increase in pulse rate, a paling of the mucous membrane throughout the organism and an increase in respiration rate. This is probably related to the autonomic system (reflex nervous system). Studies of animals and humans show that this effect is temporary. There are no valid data to show that they carry over to produce permanent effects."

Reference 4 states:

"Because of adaptation, one could anticipate that regular, expected noise may in general have no adverse effects on nonauditory mental or motor work performance or output. Indeed, in our opinion, the experimental data to be presented show this to be the general fact of the matter."

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[1] See REFERENCES, p. 23.

Reference 5 indicates that exposure to acoustic noise above certain levels for specific periods of time is permanently damaging to hearing. Recent federal legislation has recognized the importance of reducing noise hazards in work situations, by establishing maximum noise levels and exposure times. A revision of the Walsh-Healey Public Contracts Act,[6] the William-Steiger Occupational Safety and Health Act of 1970,[7] other federal Acts, and a BUMED Instruction,[8] all address the problem, and are based on the same noise criteria. The limits they establish are set to protect 80 percent of the personnel exposed to the noise. Scientific groups, in general, prefer levels 5 dB less than the limits set by these regulations, and the lower levels have been recommended in a new NIOSH (National Institute for Occupational Safety and Health) document,[9] but so far the more stringent requirements have not been written into regulations or laws.

Table 1 lists the exposure limits and sound levels set by the Walsh-Healey Act. Table 2 shows the individual octave-band levels that correspond to the 90-dB A-weighted levels in table 1. In the discussion of results, to be presented in a later section, the areas of the radar system where the noise levels exceed 90 dBA will be identified.

TABLE 1. WALSH-HEALEY EXPOSURE LIMITS BEFORE ONSET OF PERMANENT HEARING DAMAGE.

Duration per Day (*hr*)	Permissible Sound Level (dBA)
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
3/4	107
1/2	110
1/4	115 max

TABLE 2. INDIVIDUAL OCTAVE-BAND LEVELS THAT CORRESPOND TO 90-dBA NOISE.

Octave Band Center Frequency (Hz)	Level (dB re 20 $\mu N/m^2$)
125	103
250	96
500	92
1000	88
2000	86
4000	86
8000	88

EFFECTS OF NOISE ON COMMUNICATION

The effects of noise on speech communication are well recognized. As in the studies on hearing hazards of noise, there are optimum, marginal, and unacceptable limits of noise in the vicinity of the talker and the listener. These limits have been well established and are used as criteria in the measurements to be reported here.

Figure 1 interprets the effects of noise on face-to-face communications in terms of permissible distances between talkers and listeners for reliable communication.[10] The permissible distances are a function of voice level as indicated in the figure; however, in general, the voice level itself is determined by the noise background and for everyday conversation the "Expected Voice Level" contour should be used. If communications are absolutely vital, voice levels can and will be raised to the "communicating voice" level but these levels cannot be maintained on a continual basis without vocal strain becoming apparent.

In interpreting figure 1, a value judgment has to be made as to what is an acceptable distance over which people should be able to converse in an "expected voice level." For many noisy situations, in ship spaces or aircraft cabins, where it is necessary to communicate to perform essential jobs, a distance of 3 feet has been specified.[11] This limits the acceptable level of noise to 70 dBA* or, more accurately, 64 dB PSIL.** If only short and/or infrequent conversations are required, greater levels can be accepted. For example, the interior levels in commercial jet aircraft cabins are roughly 80 dBA or 74 dB PSIL. The decision to be made for radar shelters is: how important is continual conversation to job performance? If it is important, 70 dBA should be specified; if it is not important, levels as high as 90 dBA could be accepted. These "design" limits are indicated in figure 1.

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*Sound-level meters conventionally have three frequency-weighting networks called A, B, and C. An A-weighted measurement corresponds roughly to how the ear "hears" the noise in terms of loudness and/or interference with speech. For convenience the A-weighted level in decibels (dB) is sometimes called dBA. A-weighted levels progressively discount sound energies at frequencies below 1000 Hz.

**PSIL (Preferred Frequency Speech Interference Level) is the arithmetic average of the measured sound-pressure level in decibels in the three octaves centered at 500, 1000, and 2000 Hz. It is expressed in decibels (dB).

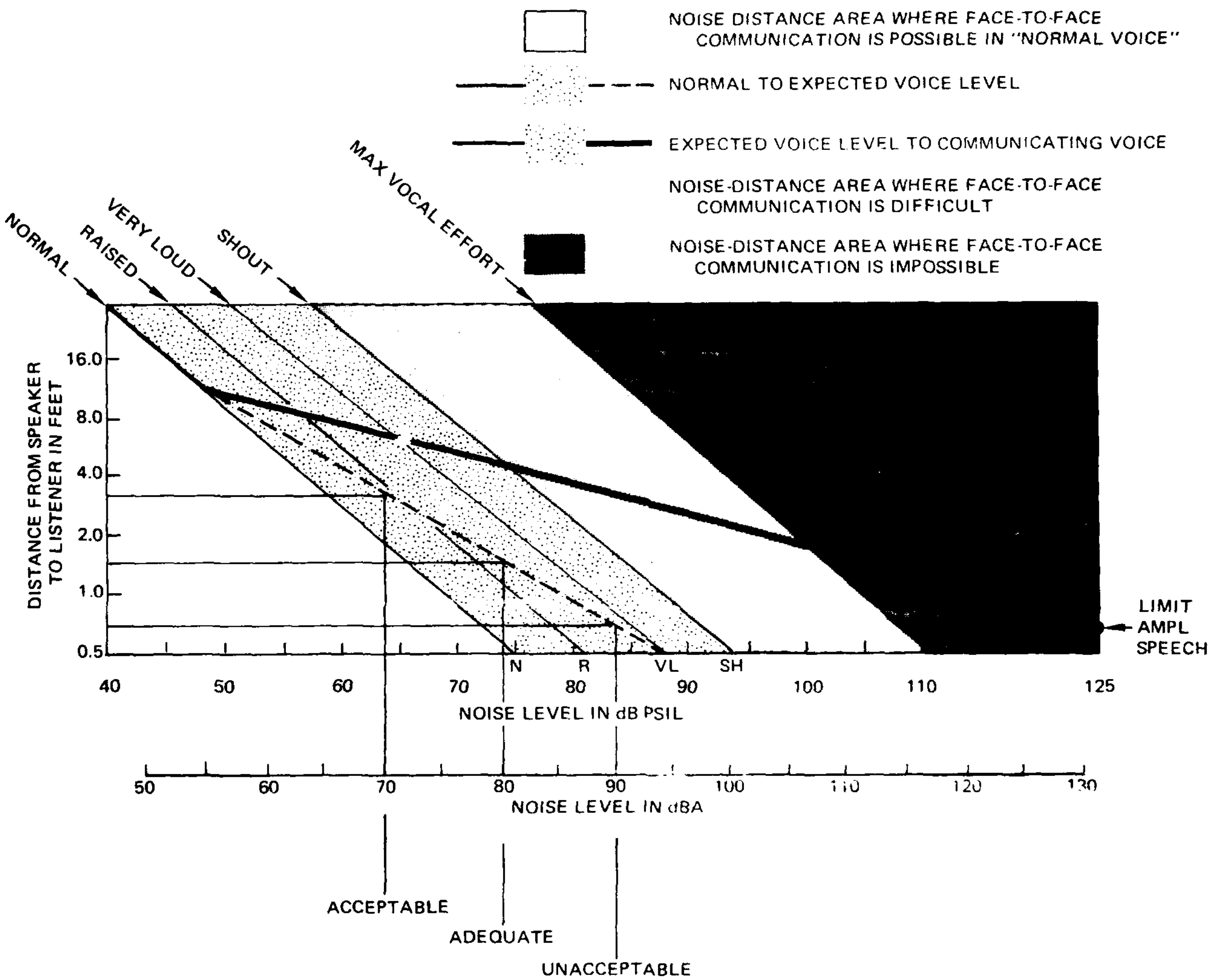

Figure 1. Effects of noise on face-to-face communications in terms of distances between talker and listeners. "Expected voice level" line shows natural compensation of voice level with increasing noise level.

STUDY APPROACH

To assess the noise environment around a typical AN/TPS-32 radar installation, a detailed survey was made at Marine Corps Tactical System Support Activity (MCTSSA), Marine Corps Air Station (MCAS) (Helicopter), Santa Ana, California. The arrangement of the AN/TPS-32 radar sites will not be identical from one location to another, but the general layout at Santa Ana, as shown in figure 2 is typical.

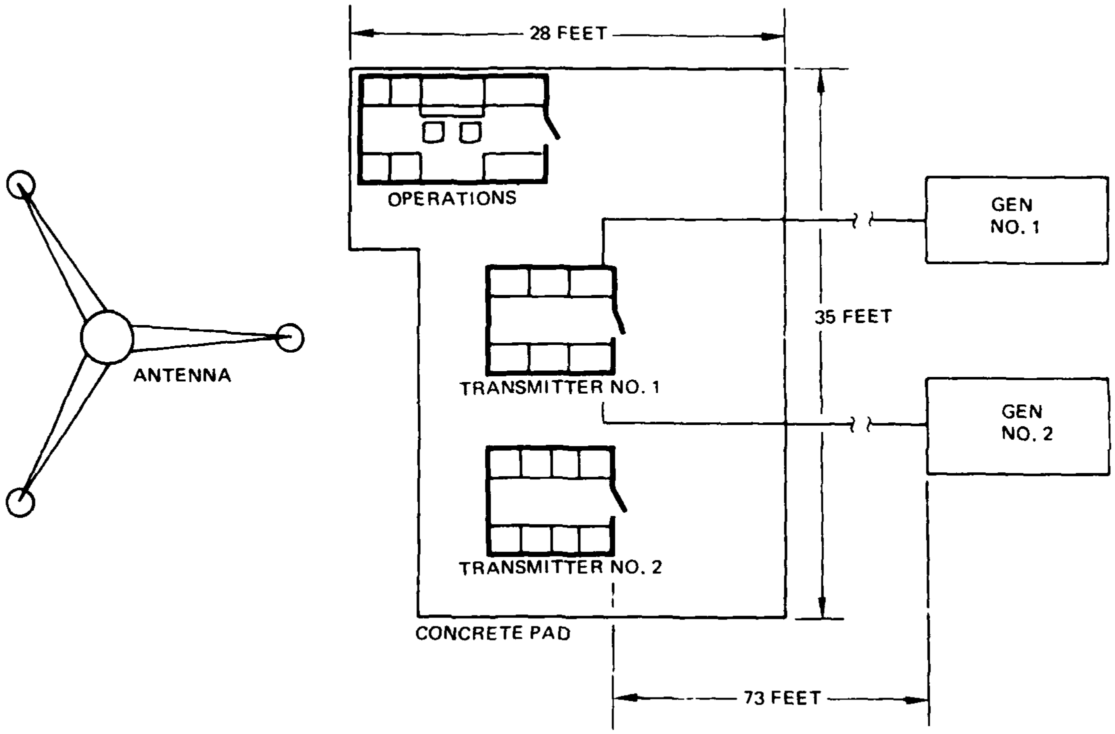

Figure 2. Physical layout of the AN/TPS-32 radar system.

MEASUREMENT METHODS

The first step in the measurement program was to identify the sources of noise and the noise-transmission or radiating paths. This was done by listening, recording all sound and vibration, and then performing narrowband wave analyses to depict the frequency and level of each resonance. The general plan of measurement, instrumentation, and presentation of results is described and illustrated in the appendix. Block diagrams of the instrumentation used for recording and for performing the narrowband analyses are included.

INTERPRETATION OF MEASUREMENTS

The major results of the noise survey are shown in figures 3-5. (Details of the contour mapping are given in the appendix.) The physical parameters of steady-state noise which are important in terms of their effects on people are presented in terms of equal-level contours for combination of octave bands and A-weighted meter readings (slow meter action).

Figure 3 indicates the noise levels that exceed the limits given in tables 1 and 2. The dBA contours are coded to indicate the areas in which personnel should not exceed 3-, 4-, or 6-hour exposures, according to the Walsh-Healey Act. Longer exposures, especially on a daily basis, can result in permanent hearing loss. (These limits protect only 80 percent of the population; the other 20 percent would sustain hearing damage with less exposure time.) It has been contended[12] that lower noise levels should be used to determine the equivalent 90-dBA octave band levels, since dB addition of all specified maximum octave band levels is equivalent to 96 dBA. For this report, in those small areas where all four octave band overlays coincide, the dBA reading is approximately 96 dBA and is plotted as such.

The wave analysis of the noise reveals many strong tonal components. Kryter[13] states that up to 5 dB should be added to the octave-band-level readings when a strong pure-tone component exists and the readings are being used to estimate auditory effects. In plotting the figures, corrections for pure tones were not incorporated because no official criteria were available. If pure-tone corrections were made, the areas outlined would cover a much greater area, indicating that the noise is considerably more hazardous than it now appears.

In figure 5, the PSIL contour indicates the noise levels in the vicinity of the radar system that exceed 65 dB and thereby degrade face-to-face communication. The three areas called out on the figure (which correspond to limits given in fig. 1) are: (1) acceptable — that is, if two people in this area speak in a raised voice and stand between 1.5 and 3.5 feet away from each other, most of what they say will be understood; (2) adequate — that is, two people have to stand within 1.5 feet of each other in order to be understood; and (3) unacceptable for face-to-face communication.

Reference 14 presents the results of earlier detailed analyses of the levels and spectra of the noise in terms of contours of equal sound-pressure levels around the area of the AN/TPS-32 radar shelters. These levels are interpreted in terms of potential damage to hearing, effects on speech communications, and certain nonauditory effects. Reference 15 contains detailed recommendations on how to reduce the noise generated or radiated from identified noise sources.

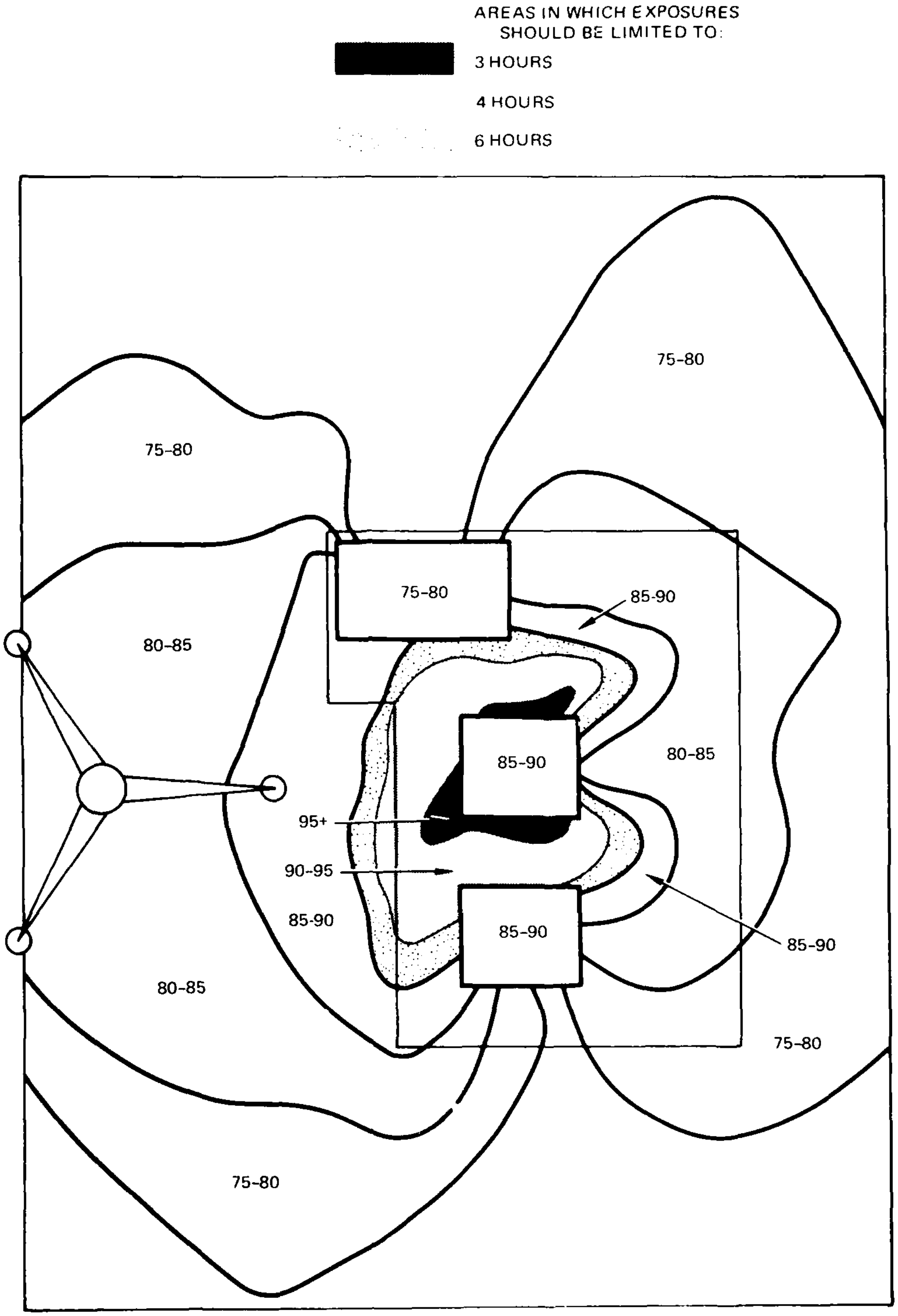

Figure 3. Variations in dBA levels shown as equal-level zones (65-70 to 95+ dBA) before modification.

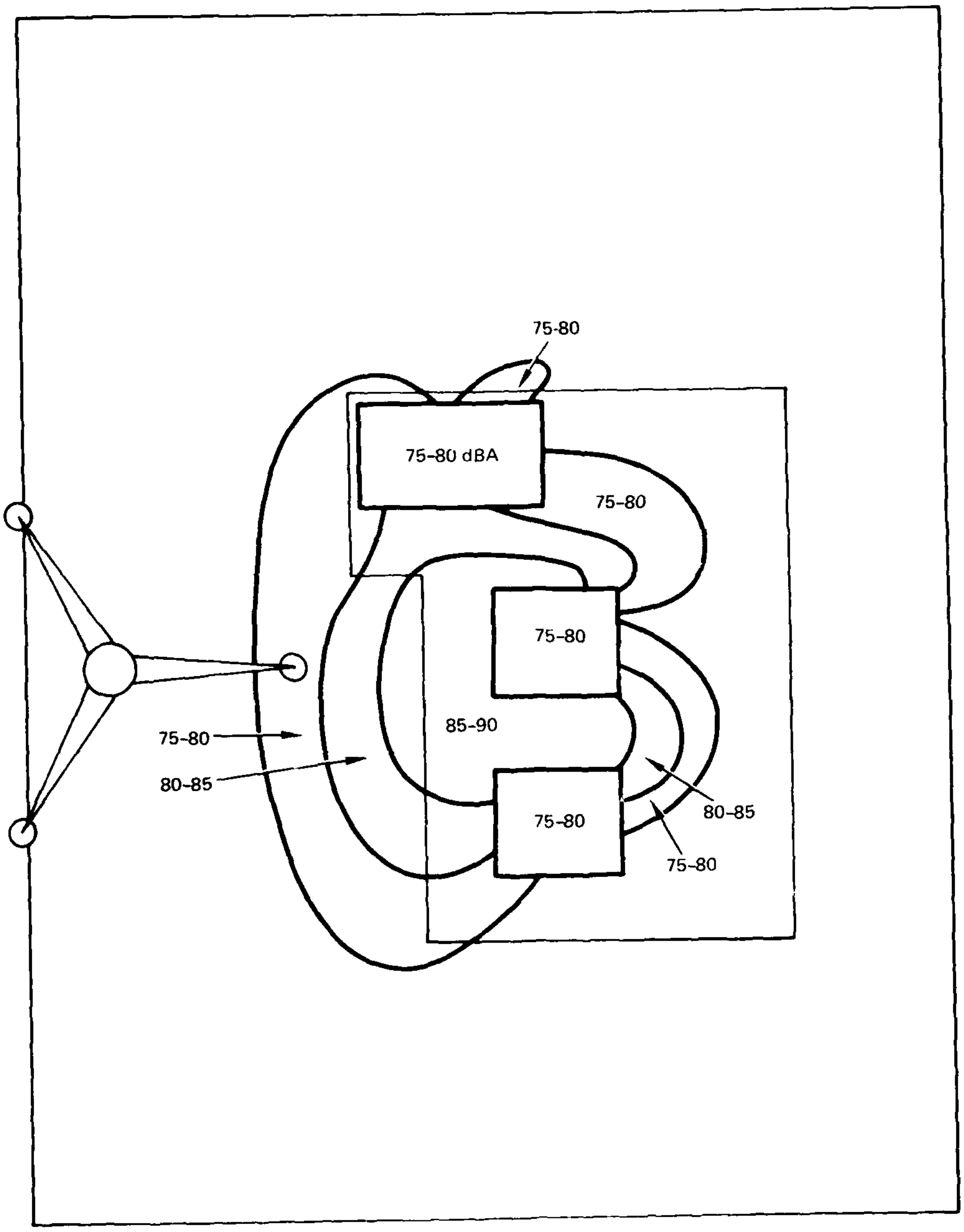

Figure 4. Estimated sound levels in dBA for moderate noise reduction and control with no extra items to be stowed during transit.

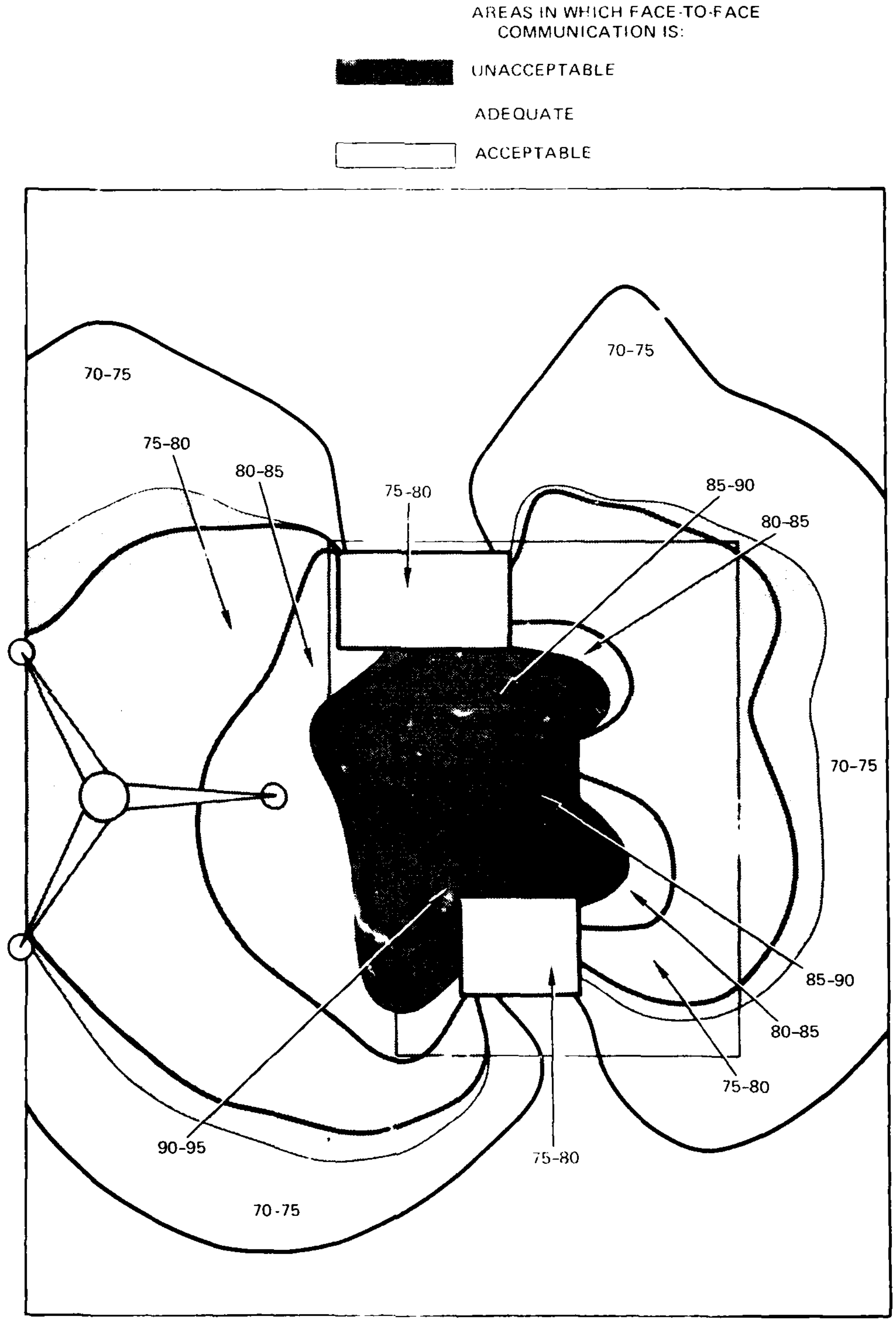

Figure 5. Variations in speech-interference levels, PSIL, shown as equal-level zones (60-65 to 90-95 dB SIL) before modification

NOISE SOURCES AND PATHS

The listening, recording, and wave analysis isolated and located two major types of noise source: rotating machinery; and turbulence, associated with fans, pumps, generators, and air conditioners housed in AN/TPS-32 transmitter shelters 1 and 2 (fig. 2).

The acoustic noise generated by these sources reached personnel by (1) direct airborne radiation; (2) transmission of airborne noise through rack panels, intake filters, and heat exchangers; and (3) transmission of vibration to racks and shelters which in turn radiate the noise to the air.

All of the offending noises consist of strong tonal components which are especially annoying and hazardous to hearing. A listing of sources, frequencies, and levels of major tonal components which produce the noise hazard is shown in table 3. The sources were identified by analysis of overall noise spectra as taken inside each shelter and in high noise areas outside the shelters.

TABLE 3. CHARACTERISTICS (SOURCE, FREQUENCY, AND LEVEL) OF OFFENDING TONAL COMPONENTS.

Description		Airborne Noise			Structure-borne Noise	
5-inch fan	Source*	BF_0	BF_1	BF_2	R_0	
(vane axial)	Frequency	650 Hz	1300 Hz	1950 Hz	130 Hz	
	Level	90 dB	86 dB	74 dB	1 g	
10-inch fan	Source*	BF_0	BF_1	BF_2		
(vane axial)	Frequency	390 Hz	780 Hz	1170 Hz		
	Level	93 dB	81 dB	86 dB		
Coolant pump	Source*	X			X	X
	Frequency	3100 Hz			125 Hz	800
	Level	90 dB			2 g	0.5 g
8-inch fan	Source*	BF_0			R_0	R_1
(propeller)	Frequency	340 Hz			85 Hz	170 Hz
	Level	85 dB			1 g	0.8 g
Air conditioner	Source*	Compressor		BF_0	Compressor	
	Frequency	125 Hz		220 Hz	125 Hz	
	Level	93 dB		93 dB	1 g	
Dummy	Source*	BF_0				
Load Fan	Frequency	1900 Hz				
(vane axial)	Level	87 dB				

*BF_0 = Blade frequency, BF_1 = 1st harmonic, BF_2 = 2nd harmonic
R_0 = Rotational speed, R_1 = 1st harmonic, X = undefined

PROBLEMS ASSOCIATED WITH THE CORROSIVE ATMOSPHERE

Subsequent to the initiation of the project, NELC investigators were informed that there were also serious corrosion problems associated with the AN/TPS-32 radar system and assumed that any noise-control techniques would have to be compatible with corrosion-control measures.

The electronic equipment is cooled by three different methods simultaneously:

1. Outside air drawn in through filtered intakes and exhausted through fans.

2. Interior fans directed at particular items for spot cooling; and

3. A liquid coolant system incorporating a heat exchanger, a 10-inch vane axial fan, a pump, and a system of pipes.

Only the first method, which relies on the outside air, would affect corrosion due to dust and moisture. The movement of the air through the equipment is best analyzed at three stages as it:

1. Enters the system through the filters and spaces in the equipment racks when the shelter doors are left opened;

2. Traverses through the equipment from the filtered intake to the exhaust fan; and

3. Exits through the fan.

Improved filters are being designed and tested by the system manufacturer and the Marine Corps, so it is not necessary to examine that problem here.

Once the proper dust filters have been installed, moisture is the remaining problem as the air flows through the system. Dehumidifiers are bulky and therefore impractical if not provided for initially. A simple method that could be used to minimize condensation would be to delay the operation of the fans until the equipment is warmer than the outside air, since it is the moist warm air flowing over the cold metal that produces the condensation. This would require a control circuit and an additional set of sensors for the outside temperature. The liquid coolant system and the interior fans would remain operative to protect the special circuits, and if necessary a few additional small fans could be added to protect other delicate circuits. The latter method would offer side benefits by reducing (1) total noise exposure, by a slight amount, (2) build-up of dust on the filters, and (3) power consumption.

As the system is now designed it is possible for dust to enter the system through the fans, especially when they are not working. One sure way to prevent this is to place a filter at the fan. If mufflers are used to reduce the noise of the fans, the filters would not be necessary. The filter and muffler load the fan to some degree but do not raise the negative pressure inside the system.

The rate of air flow through the system is mostly determined by the fans. Maximum air flow is required only at or near maximum temperatures. Since maximum temperatures are seldom reached, air flow could be less than maximum most of the time, thereby reducing contamination and loading on the filters.

Air flow can be reduced by adding dampers or louvers, or by adding a slower second speed to the fan motor. A two-speed fan would produce less noise and require less power during slower-speed operation, but temperature-control circuits would be required to select the proper speed; however, dampers are the less expensive method.

TECHNIQUES FOR NOISE REDUCTION AND CONTROL

Table 4 lists (1) all major noise reduction/control points in the system, (2) individual noise reduction/control techniques for six potential modification kits, (3) cost and expected noise reduction (expressed in dBA) for each individual solution, (4) estimated overall cost of each potential kit, and (5) estimated equal-level noise contours after installation of each modification kit.

One point which cannot be adequately covered in the table concerns the HD-706 air conditioner, which is a major source of noise and vibration, necessitating costly noise-reduction modifications to the radar system. These air conditioners are scheduled to be replaced eventually by MAC-4V20 air conditioners, which are situated on the ground apart from the shelter and are connected to the radar system with flexible ducting. Any modifications to the shelter air-conditioner supports or any skids and baffles built to reduce the noise caused by the HD-706 would be outdated shortly after they were implemented. Therefore, it is strongly recommended that the MAC-4V20 air conditioner be scheduled to replace the HD-706 at the same time that the noise-reduction modification kits are to be installed on the AN/TPS-32 radar system.

Table 4 consists of facing foldouts. →

Noise Sources With Pos

Nomenclature of noise source:	5" Fan	Coolant System				8" Fan
Quantity of noise source:	7	2				4
Location of noise source:	Xmitters 1 & 2	Xmitter Shelters 1 & 2				OPS Shelter
Subdivisions of noise source:		10" Fan	Heat Exchanger	PUMP	ENCLOSURE	
Possible overall solutions 1. Bare minimum of modifications for 90 dBA requirement.	Sound-absorbing material under rain shield and between fan and outer grill.	Sound-absorbing material under rain shield and/or noise-attenuating louvers.	Sound-absorbing material under rain shield.		Sound-absorbing material in convenient areas.	Sound-absorbing material under rain shield.
Price/Improvement	$1400/8 dBA	$480/8 dBA	$10/3 dBA		$10/3 dBA	$10/2 dBA
2. Moderate noise reduction and control with no constraints.	Duct silencer on exhaust, aerodynamic intake, vibration isolators.	Duct silencer on exhaust.	Sound-absorbing material under rain shield.	Vibration isolation pads.	Sound-absorbing material in convenient areas.	Noise-attenuating louvers on exhaust an damped moun ing plate.
Price/Improvement	$2275/16 dBA	$800/10 dBA	$10/3 dBA	$25/2 dBA	$10/3 dBA	$1320/10 dB
3. Maximum noise reduction and control with no constraints.	Replace with two-speed fan mounted on damped plate and duct silencer on exhaust.	Duct silencer on exhaust and damped mounting plate.	Noise attenuating louvers on exterior.	Vibration isolators.	Sound-absorbing material in convenient areas.	Duct silencer on exhaust, t speed motor, and damped mounting pla
Price/Improvement	$5110/30 dBA	$1080/13 dBA	$600/10 dBA	$50/2 dBA	$10/3 dBA	$2200/15 dB

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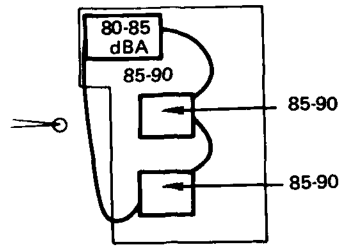
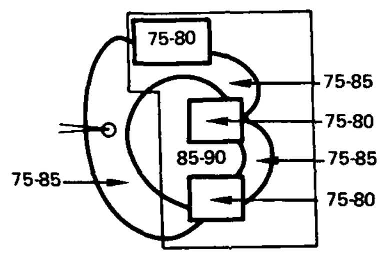
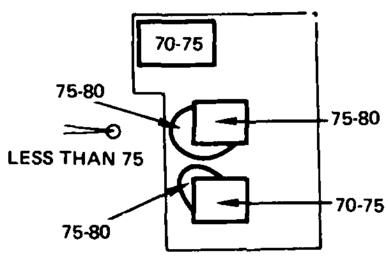
TABLE 4. SIX POSSIBLE SOLUTIONS TO ACOUSTICAL NOISE PROBLEM OF THE AN/TPS-32 RADAR SYSTEM.

urces With Possible Noise Reduction or Control Techniques							Advantages
8" Fan	Air Conditioner		Shelters	Filter Intake	Dummy Load Fan	Generators	
4	3		3	10	2	2	
OPS Shelter	(One for each shelter)		(See fig. 2)	On each shelter	Base of Antenna	(See fig. 2)	
	OPS Shelter	Xmitter 1 & 2					
Sound-absorbing material under rain shield.	Lined duct with bend on compressor exhaust.						Hearing protectors would not be required.
$10/2 dBA	$195/6 dBA						Subtotal $2105
Noise-attenuating louvers on exhaust and damped mounting plate.	Vibration isolation from shelters, sound-absorbing barrier in front of compressor exhaust, and line existing duct with sound-absorbing material;	replace air register with noise attenuating louvers.	Sound-damping material applied to interior and exterior wall surfaces and sound-absorbing material on ceilings and upper wall behind console.	Sound-absorbing material under rain shield.	Barrier lined with sound-absorbing material.	Sound-deflecting barrier.	Hearing protectors would not b required; face-to-face commun cation would be possible with shouting but with slightly raise voice.
$1320/10 dBA	$2320/5 dBA		$2600/4 dBA	$30/2 dBA	$300/10 dBA	(Note 2)	Subtotal $9690
Duct silencer on exhaust, two-speed motor, and damped mounting plate.	Remove shelter mounts and place on skids with duct silencer on compressor exhaust, adapt to flexible ducting, and line existing duct with sound-absorbing material;	replace air register with lined duct.	Sound-damping material applied to interior and exterior wall surface and sound-absorbing material on ceilings and walls.	Duct silencer on exterior.	Lined duct on intake and duct silencer on exhaust.	Ventilated soundproof enclosure	Hearing protectors would not required; face-to-face commu cation would be possible in normal speaking voice.
$2200/15 dBA	$3200/15 dBA		$2600/4 dBA	$400/6 dBA	$300/15 dBA	$5000/10 dBA	Subtotal $24,180

-32 RADAR SYSTEM.

Advantages	Total Costs (Note 3)	Estimated Noise Field	NOTES
	(1 System) [13 Systems]		1. If MAC-4V20 air conditioners are adapted along with this mod kit, it would only be necessary to adapt the shelters to flexible ducting (about $60) and treat interior duct and registers. 2. These barriers are now being used with MTDS systems. No data are available. 3. Total costs include subtotals for parts and $2400 for temperature controls circuits plus a 20% additional fee for management and documentation.
Hearing protectors would not be required. Subtotal $2105	($5400) [$70,000]	 BARE MINIMUM OF MODIFICATION FOR 90-dBA REQUIREMENT	
Hearing protectors would not be required; face-to-face communication would be possible without shouting but with slightly raised voice. Subtotal $9690	($14,500) [$189,000]	 MODERATE NOISE REDUCTION AND CONTROL WITH NO RESTRAINTS	
Hearing protectors would not be required; face-to-face communication would be possible in normal speaking voice. Subtotal $24,180	($31,900) [$415,000]	 MAXIMUM NOISE REDUCTION AND CONTROL WITH NO CONSTRAINTS	

Noise Sources With Po

Nomenclature of noise source:	5″ Fan	Coolant System				8″ Fan
Quantity of noise source:	7	2				4
Location of noise source:	Xmitters 1 & 2	Xmitter Shelters 1 & 2				OPS Shelter
Subdivisions of noise source:		10″ Fan	Heat Exchanger	PUMP	ENCLOSURE	
Possible overall solutions						
4. Moderate noise reduction and control with no extra items to be stowed during transit.	Replace with two-speed fan-curb silencer, vibration-isolator combination, and sound-absorbing material under rain shield.	Noise-attenuating louvers on exhaust, and sound-absorbing material under rain shield.	Sound-absorbing material under rain shield.	Vibration isolation pads.	Sound absorbing material in convenient areas.	Sound-absorbing material under rain shield; filter between fan and outer grill; damped mounting plate.
Price/Improvement	$4200/17 dBA	$600/3 dBA	$10/3 dBA	$25/3 dBA	$10/2 dBA	$160/3 dBA
5. Maximum noise reduction and control in operations shelter and minimum modification for 90 dBA elsewhere.	Sound absorbing material under rain shield and between fan and outer grill.	Sound absorbing material under rain shield and/or noise attenuating louvers.	Sound-absorbing material under rain shield.		Sound-absorbing material convenient areas.	Duct silencer on exhaust, two-speed motor, and damped mounting plate.
Price/Improvement	$1400/8 dBA	$600/8 dBA	$10/3 dBA		$10/3 dBA	$2200/15 dBA
6. Maximum noise reduction and control without replacing any major components.	Duct silencer on exhaust; aerodynamic intake; vibration isolators.	Duct silencer on exhaust and damped mounting plate.	Noise attenuating louvers on exterior.	Vibration isolators.	Sound-absorbing material in convenient areas.	Duct silencer on exhaust.
Price/Improvement	$2275/16 dBA	$1080/13 dBA	$600/10 dBA	$50/2 dBA	$10/3 dBA	$1100/10 dBA

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TABLE 4 (Continued)

th Possible Noise Reduction or Control Techniques							Advantages	Total (No
n	Air Conditioner		Shelters	Filter Intake	Dummy Load Fan	Generators		
	3		3	10	2	2		(1 Syst
lter	(One for each shelter)		(See fig. 2)	On each shelter	Base of Antenna	(See fig. 2)		[13 Sys
	OPS Shelter	Xmitter 1 & 2						
sorb- ial n ter fan r grill; mount-	Remove shelter mounts and place on skids with barrier on compressor exhaust, adapt to flexible ducting and line existing duct with sound absorbing material;	replace air register with noise attenuating louvers.	Sound-absorbing material on ceilings and upper wall behind console.	Sound absorbing material under rain shield.	Duct silencer on exhaust.	Sound-deflecting barrier.	Same as (2) above; also, no additional time would be required to set up or to pack up the radar system.	($13 [$16
BA	$3150/6 dBA		$60/3 dBA	$30/2 dBA	$200/12 dB	(Note 2)	Subtotal $8445	
ncer st, d nd	Remove shelter mounts and place on skids with lined barrier on compressor exhaust, adapt to flexible ducting and line existing duct.	Lined duct with bend on compressor exhaust.	Sound-absorbing material on ceiling and walls of operations shelter.	(OPS shelter only) duct silencers on exterior.			Hearing protectors would not be required; face-to-face communication would be possible inside operations shelter in normal speaking voice.	($11, [$155
5 dBA	$2900/6 dBA		$50/3 dBA	$350/4 dBA			Subtotal $7520	
ncer st.	Vibration isolation from shelters, duct silencer on compressor exhaust and line existing duct with sound absorbing material;	replace air register with lined duct.	Sound-damping material applied to interior and exterior wall surfaces; and sound-absorbing material on ceilings and walls.	Duct silencer on exterior.	Lined duct on intake and duct silencer on exhaust.	Ventilated soundproof enclosure.	Same as (3) above; also, no components would have to be qualified.	($26, [$338
0 dBA	$2200/15 dBA		$2600/4 dBA	$4000/6 dBA	$330/15 dBA	$5000/10 dBA	Subtotal $19,245	

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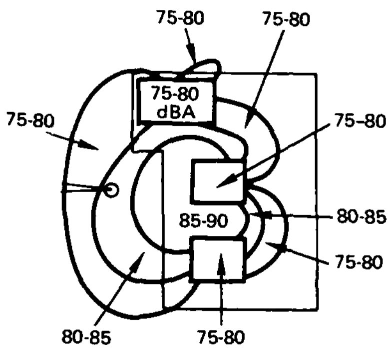
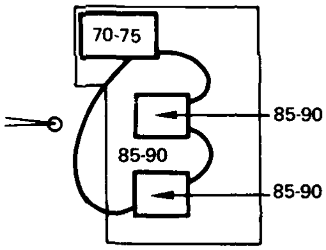
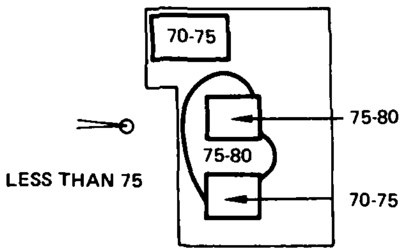
	Advantages	Total Costs (Note 3)	Estimated Noise Field	NOTES
nerators 2 e fig. 2)		(1 System) [13 Systems]		
l-deflect- rrier.	Same as (2) above; also, no additional time would be required to set up or to pack up the radar system.	($13,000) [$169,000]	MODERATE NOISE REDUCTION AND CONTROL WITH NO EXTRA ITEMS TO BE STOWED DURING TRANSIT	
2)	Subtotal $8445			
	Hearing protectors would not be required; face-to-face communication would be possible inside operations shelter in normal speaking voice.	($11,900) [$155,000]	MAXIMUM NOISE REDUCTION AND CONTROL IN OPERATIONS SHELTER AND MINIMUM MODIFICATION FOR 90 dBA ELSEWHERE	
	Subtotal $7520			
ited roof re.	Same as (3) above; also, no components would have to be qualified.	($26,000) [$338,000]	MAXIMUM NOISE REDUCTION AND CONTROL WITHOUT REPLACING ANY MAJOR COMPONENTS	
10 dBA	Subtotal $19,245			

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3

RECOMMENDATION FOR MODIFICATION KIT

Preliminary recommendations for a noise-reduction modification kit for the AN/TPS-32 radar system have been jointly reached by personnel from NAVELEX, HQMC, and NELC.[16] Each item was considered on the basis of its impact on:

1. System assembly time in the field,
2. Storage of removable items during transit,
3. Qualification of new items,
4. Effect of noise on hearing and face-to-face communication,
5. Corrosion within the system,
6. Field installation, and
7. Cost of the kits.

The kit chosen as the most suitable is described as Combination 4 in table 4, with the notation "Moderate noise reduction and control with no extra items to be stowed during transit." Another detail of Combination 4 is noted in the section on Problems Associated with the Corrosive Atmosphere: "Keep the fans off until equipment is warmer than outside air."

In summary, this kit would include (1) some new fans, sound-absorbing material, and duct and louvered silencers to reduce the level of the directly radiated noise; (2) vibration-isolating materials to reduce the transmission of vibration to radiating surfaces; and (3) sensing circuits to control the air flow and thus reduce the severity of corrosion. The impact of this kit on the acoustic noise of the radar system is demonstrated by a comparison of the present and predicted noise contours and present and predicted PSIL contours shown in figures 3, 4, 5, and 6, respectively.

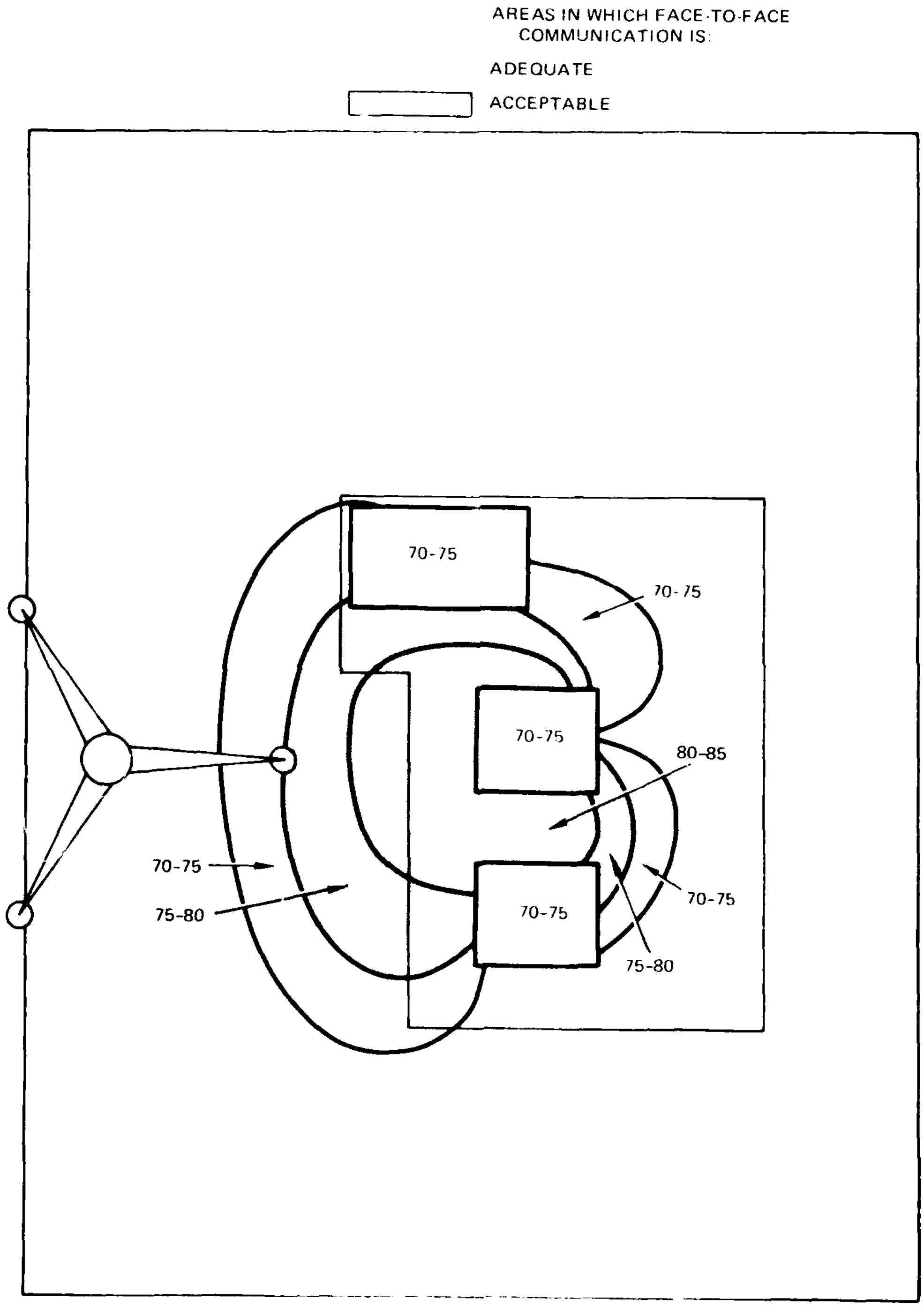

Figure 6. Estimated levels in dB PSIL for moderate noise reduction and control with no extra items to be stowed during transit.

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16. NAVELEX (U) Letter 05425: 1EK: db, P02-0061 Serial 360-0542 to NELC, Subject: *AN/TPS-32 Noise Reduction Report Comments,* 27 December 1972

*NELC Technical Notes are informal publications intended primarily for use within the Center.

APPENDIX: DETAILS OF NOISE CONTOUR MAPPING AND TONAL COMPONENT ANALYSES

NOISE CONTOURS

Contour mapping of noise levels was selected for the presentation of the noise analysis on the AN/TPS-32 radar system because the hundreds of data points are easily and quickly interpreted. The methods used to obtain the data and to draw the contours are detailed below.

Based on data from an earlier sound survey, a grid pattern with 5-foot intervals was chosen to delineate the points for the far-field measurements. Near-field measurement points were selected 1-1/2 to 2 feet from the shelters. Since the noise field inside the shelters was uniform, one test point was selected in each shelter.

A scale drawing of the radar system as positioned at MCTSSA was used to designate each measurement point. (See fig. A1.) This grid, which covered an area 60 by 70 feet, was duplicated at the site by using stakes and string in reticular fashion. The near-field points were chalked in on the concrete.

Ten noise measurements were taken at each data point – dBA, flat, and the octave bands centered at 63, 125, 250, 500, 1k, 2k, 4k, and 8k hertz. Instrumentation used is shown in block form in figure A2. The tripod was set up so that the microphone was at ear level above each test point, tilted for 70° incidence, and facing the center of the noise source (transmitter shelter #1). The microphone calibrator was used three times a day to assure accuracy.

Under certain measurement conditions, the level of the noise sometimes varied more than 1 dB, so, in order to eliminate judgment differences between personnel, a record was made of the upper and lower dB readings obtained in approximately a 5-second interval. Most readings did not vary more than 2 dB and a convention of plotting the upper reading for 1-dB variations and the middle value for 2-dB variations was used.

A separate grid was plotted for each of the ten measurements (i.e., dBA, flat, etc.) using corresponding levels at each test point. Points having the same values were connected with a smooth line and intermediate values were interpolated. Contours were drawn in 1-dB increments in order to reveal fine details. Five-dB increments were found sufficient to depict pattern detail and so were selected for this report.

An additional contour was plotted for the face-to-face speech interference level (PSIL), which is the arithmetic mean of the octave band levels centered at 500, 1k and 2k hertz.[10]

Only the dBA and PSIL contours are presented in this report. All of the contours were presented in reference 7.

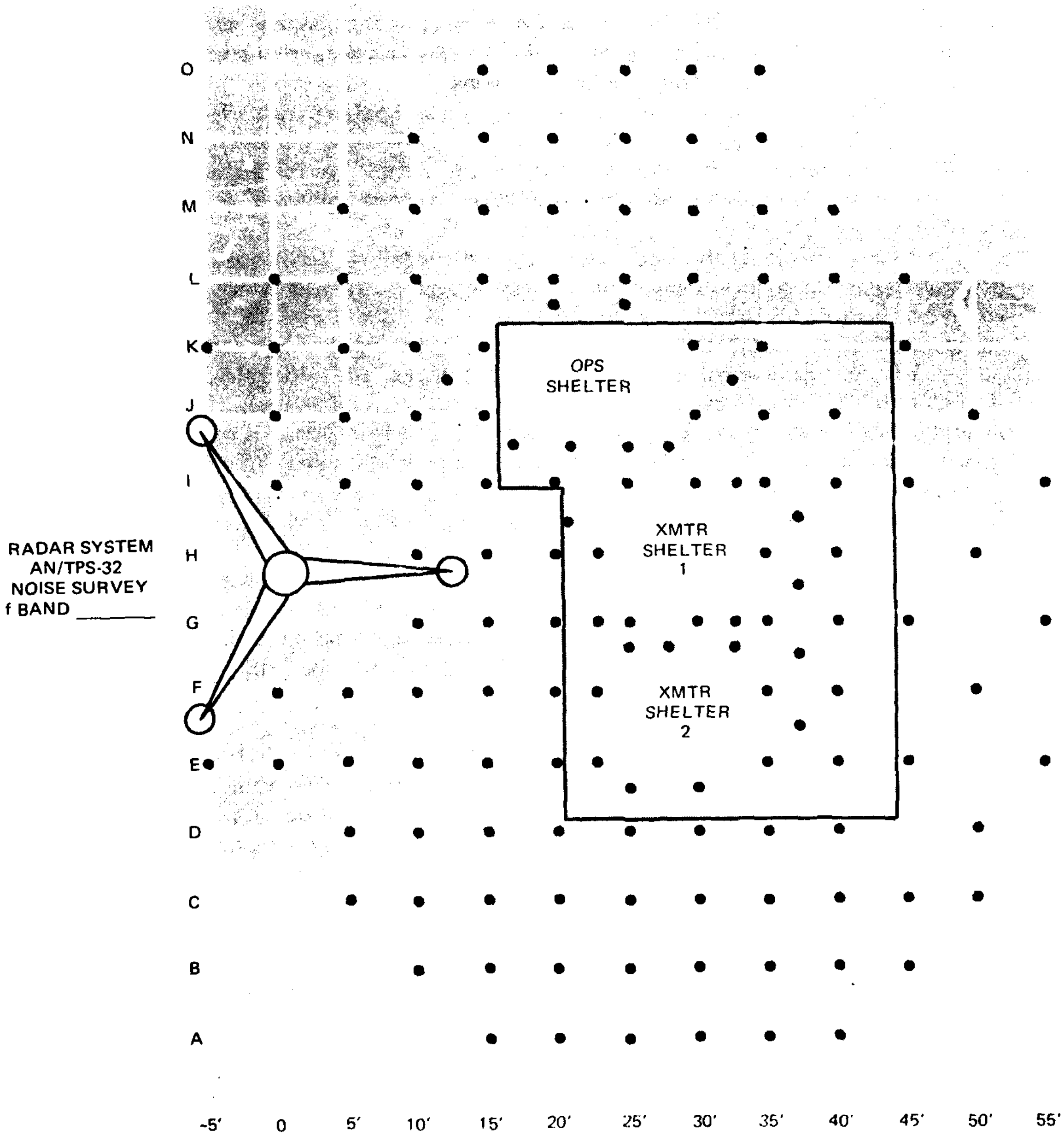

Figure A1. Scale drawing of AN/TPS-32 radar system at MCTSSA, showing microphone locations.

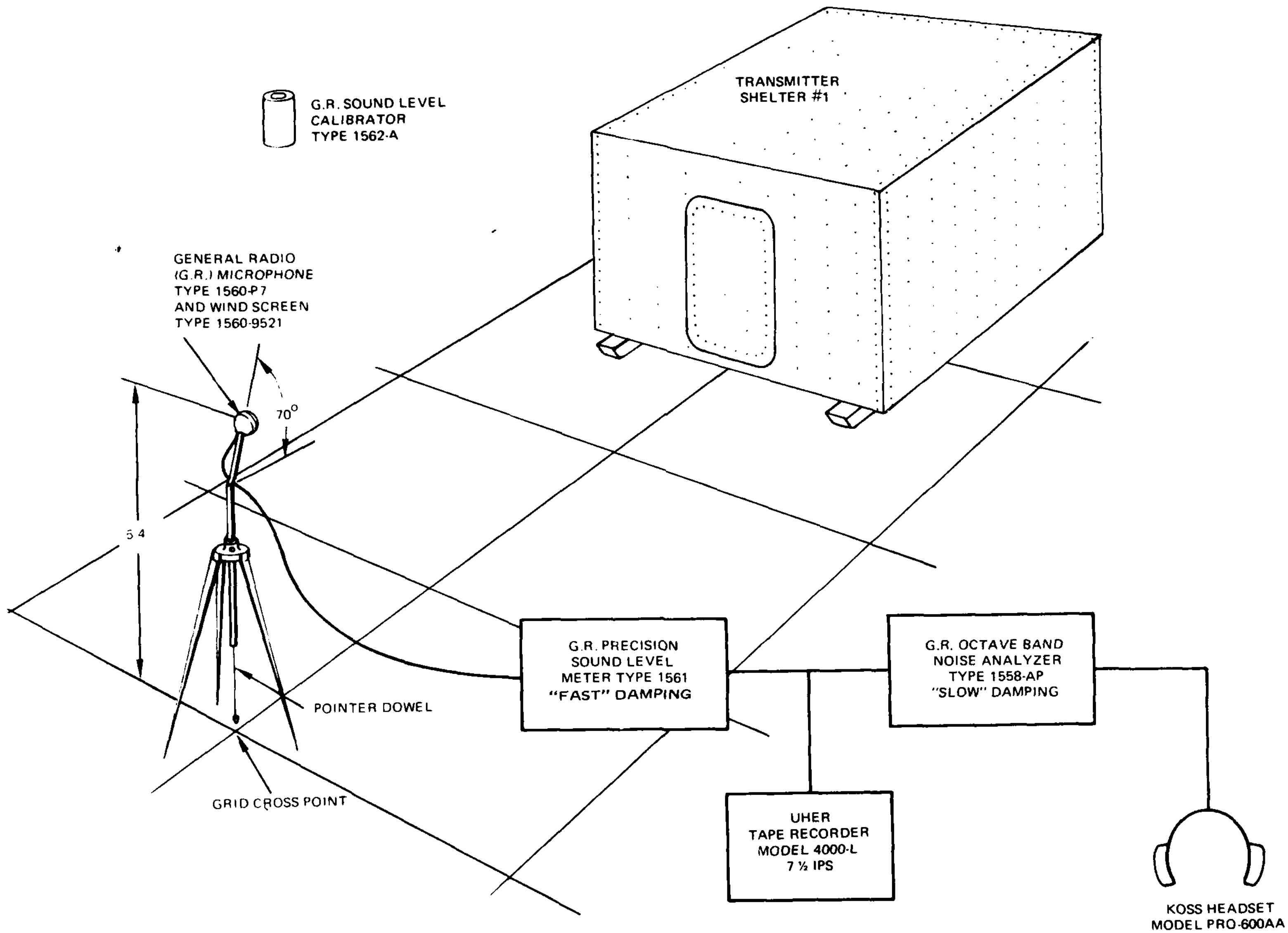

Figure A2. Orientation of instrumentation for noise measurements.

TONAL COMPONENT ANALYSES

Any time the results of noise-level surveys are plotted and analyzed in terms of octave bands, groups of octave bands (speech interference levels), or broadband, the effect of tonal components is compounded. That is, tonal components add to any band levels (octaves and broader), but have differential effects on human responses. Equivalent levels of tones, in contrast to bands, are more damaging in terms of deafness risk, but less disrupting of speech perception. In any case, locating and isolating tonal components is a good way of locating noise sources and gives strong hints of how to reduce offending noises. For this reason, narrow-band 3 and 10 Hz wave analyses were made of any noises suspected of containing strong tonal components.

Block diagrams of the instrumentation for recording and narrow-band analyzing the noise are shown in figures A3 and A4. A 3-Hz wave analysis of a tape recording of the noise between transmitter shelters 1 and 2 is shown in figure A5.

The dummy load at the base of the antenna produces a high-level, high-pitched noise; however, it is rarely used and so was not operated during the noise survey. An octave-band analysis of the noise generated by the dummy load is presented in figure A6.

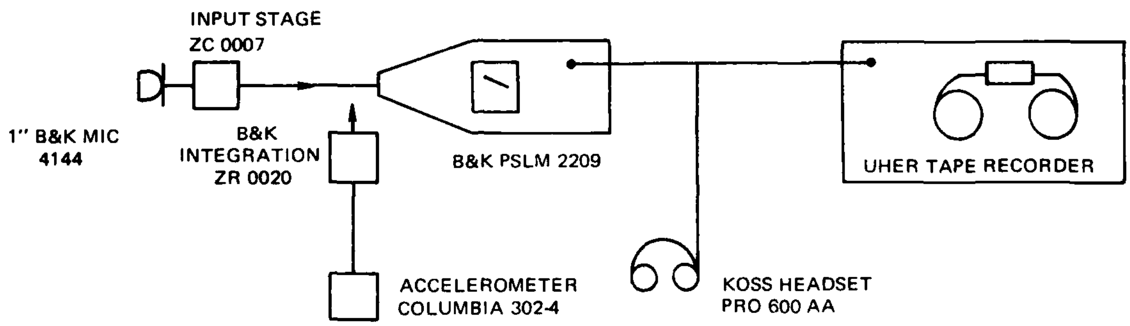

Figure A3. Instrumentation used to measure and record noise and vibration.

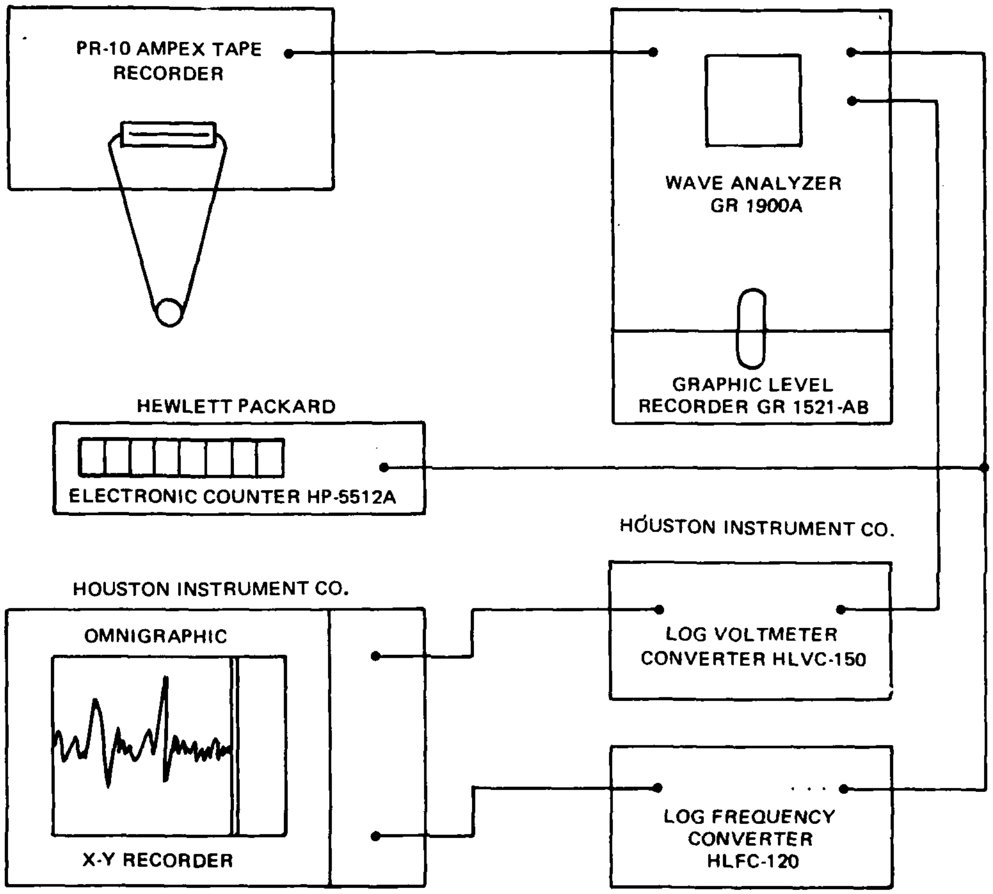

Figure A4. Instrumentation used to analyze noise and vibration.

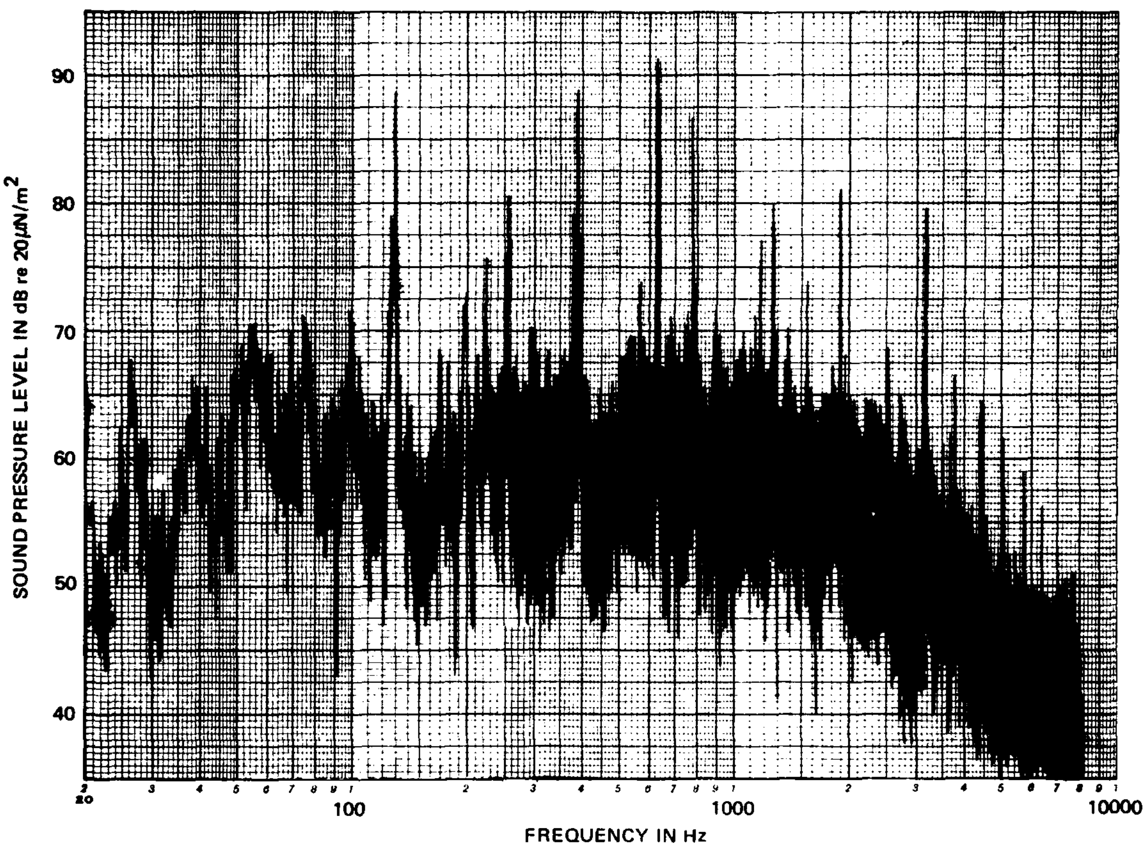

Figure A5. Wave analysis of noise recorded between transmitter shelters 1 and 2 (3-Hz bandwidth).

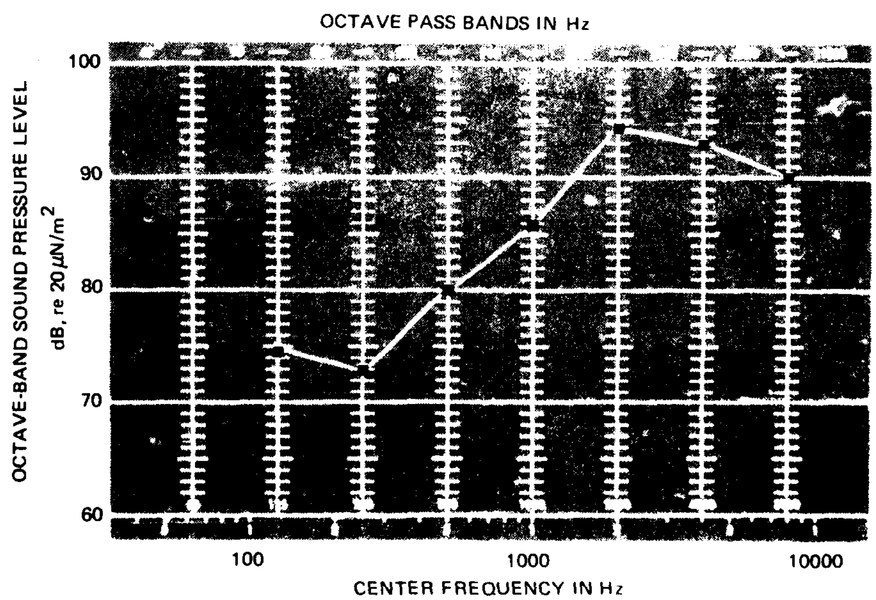

Figure A6. Octave-band analysis of noise at a position near the dummy load of the AN/TPS-32 radar system.

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13. ABSTRACT

Report of a study of the total acoustic noise environment of the AN/TPS-32 radar installation at MCAS, Santa Ana, California, in terms of hearing hazard to personnel and degradation of speech communications. Noise sources were identified, and sound-spectrum levels at each source were measured and analyzed. Several methods for reduction/control of the noise were studied; the one chosen as most effective is described.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Noise						
Noise reduction						
Noise control						
Hearing hazard						
Speech interference						